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FINAL REPORT

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TITLE: "The Ultrastructure of the Otolithic Organs in Squirrel Monkeys after Exposure to High Levels of Gravitational Force"

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PLACE WHERE RESEARCH PROJECT PERFORMED: Jointly by the U.S. Naval School of Aviation Medicine, Pensacola, Florida; and, Harvard Medical School, Boston, Massachusetts

The experiment was designed to study the problem of whether injury to the otolithic organs might occur during high acceleration on liftoff and deceleration on re-entry from space flight. Squirrel monkeys were used because of the experience with these animals in space flight and because the results in primates may, with caution, be extrapolated to man.

Eleven squirrel monkeys were exposed, either to 5.43 or 10.92 G units for one to ten minutes, in different positions in the human centrifuge at the U.S. Naval School of Aviation Medicine, Pensacola, Florida.

Exposures to 10.92 G units were tolerated for periods of one minute but longer periods of exposure resulted in ataxia for several minutes or hours, followed by recovery. The lower levels of acceleration were tolarated as long as ten minutes, although some of these animals exhibited temporary paralyses and ataxia.

Eight animals survived the exposure. Half of these were sacrificed within fifteen minutes and the others 24 hours after exposure. One of the ears was used for light microscopic study and the other for electron-microscopic study.

The brains of the animals revealed no pathologic changes on gross examination.

Light microscopic studies failed to reveal structural changes in the vestibular sensory epithelium which could be ascribed to G stress,

The celloidin sections for microscopic study were prepared at the Otopathology Laboratory in the Department of Otolaryngology at the Massachusetts Eye and Ear Infirmary, which is affiliated with Harvard Medical School.

Dr. Heinrich H. Spoendlin, Research Fellow in the Department of Otolaryngology at the Harvard Medical School for one year from July 1, 1961 to June 30, 1962, and at Yale University School of Medicine for one year from July 1, 1962 to June 30, 1963, performed the electronmicroscopic studies. He made several trips from Boston and New Haven to Pensacola and was on hand at the time that the animals were G stressed to prepare the ears for study.

In general, the sensory cells of the maculae of the squirrel monkey have the same basic structure as other mammals. The appearance of the sensory hairs of animals exposed to G stress was not different from those in normal animals. Each sensory cell carries from 60-100 stereocilia and 1 kinocilium, geometrically arranged. The apical protoplasmic protrusion of the sensory cells were not as large and abundant in the squirrel monkey as has been reported for guinea pigs but it is doubtful that this is of any special significance. Cytoplasm of the sensory cells is rich in Golgi membrane, small vesicles, vesicular bodies, and ribosomes. Numerous black inclusions in the sensory and supporting cells have the structural characteristics of lysosomes. A variety of accessory synaptic structures were found in the cytoplasm of the sensory cells. The number of synapses per sensory cell and nerve ending was found to vary greatly in both the normal and G-stressed animals.

The experiment indicated that gravitoinertial centrifugal forces of 5.43 and 10.92 G units for period of one to ten minutes produced no morphological changes in the end organs of the gravi-receptors in the maculae. The absence of any structural changes in the otolith organs under the conditions of this experiment raises two questions: (1) at what level of force will first indications of injury appear; and (2) what caused the temporary ataxia in some of the animals.

The post-stimulation ataxia cannot be attributed to end organ changes in the otolith organs but might have had its genesis in the semicircular canals. The close parallelism in the manifestation of ataxia in centrifuged human and animal subjects is of more than passing interest. Disappearance of ataxia suggests that the injury, whatever its cause, was quickly reversible and that any residuum was compensated by the redundancy of nature.

Whereas the studies of the cochlea following intense auditory stimulation show increasing numbers of osmophilic inclusions, there was no difference in the number of osmophilic granules in the hair cells of the maculae of G-stressed and unstressed monkeys. Because of the lethal effect, it is not possible to stimulate the gravity receptors to the same magnitude as is possible for acoustic receptors.

It is concluded that exposure to gravitational forces greater than 10.92 G units is necessary before physical alterations in fine structure of the macula can be demonstrated in squirrel monkeys. The possibility has not been ruled out that the clinical manifestations of ataxia following G stress may have had their genesis in the semicircular canals. If the G loadings in this experiment are not exceeded in orbital space flights, alterations of the maculae would be ascribable to other causes, including the prolonged deafferentation associated with weightlessness.